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Bunker Consumption for Tankers in Increased Speed

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ABSTRACT

This research documents aim to identify the substantial increase in bunker consumption when oil tankers are in a speedup mode. The research extends into areas of the how the tanker?s hull and propeller impact the bunkers, the requirement of speeding up in challenging weather conditions and finalizing a tool for the calculation of accurate bunker consumption with not much in increased speeds

1. Introduction.

Oil needs to be transported from refineries into terminals to further reach out in order to satisfy the energy needs of the world's growing population. Rising electricity demand, faster than global energy demand required oil to be refined and shipped to all parts of the world faster and efficiently.

In recent years, almost all private, national and international organization involved in the oil and gas industry and the business are addressing the cost of fuel efficiency of the millions of oil and LNG tankers all over the globe. This attention has come about due the rising costs of tanker fuel costs which are inevitably passed over from one party to another in the marine chain. Fuel on-board ships, commonly referred to as "bunkers", has become the largest cost item of a ship's Operational Expenses (OPEX), accounting today almost 50% of a voyage cost, even greater than crew wages.

The level of interest in designing a fuel-efficient ship is linearly related to the fuel price. Between 1970 and 1980 fuel oil price increased significantly (nearly ten-fold), leading to ships with high fuel consumption being laid up. During the period 1985– 2000 prices of fuel oil fell, with research and development on energy efficiency not receiving attention by the maritime industry. However, from 2000 onwards, the crude oil cost started to climb again, which pushed engine manufacturers, shipyards and designers to reinvestigate design and operational solutions for reduced fuel consumption and energy efficiency. Shipping is no different than other industries and is highly affected by fuel prices. However, there is, to a certain extent, a control on the ship's fuel consumption by means of technical innovation fitted or by a better ship operation such as weather routing, trimming, slow steaming, etc.

Even though oil price decreased for a brief period of time after the 2008 recession, today is again at record high levels, meaning that ship operators cannot ignore this expense as in the past, or just embody it into the price of the commodities carried, but there is a need to design and operate more efficient ships, consuming less fuel per carrying capacity.

Furthermore, the intense focus on environmental protection, supported by considerable research findings, has led the International Maritime Organization (IMO) to take concerted measures towards this direction, in limiting the environment foot print of ships significantly. In particular, one of the top environmental topics is global warming due to increasing Green House Gases (GHG) in the atmosphere. The shipping industry contributed about 4% of the world carbon dioxide (CO_2) emissions in 2007. The aim to reduce CO_2 emissions comes hand in hand with the increasing fuel price, and is leading towards the adoption of technological and operational innovations in order to decrease fuel consumption. In order to set means to improve ship's fuel efficiency, it is initially required to define the

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prevailing fuel consumption rate. For this purpose, the importance of carrying out a full scale ship performance analysis is highlighted in several publications as offering benefits to the designers and the operators. The aim of such an analysis can, for example, be the prediction of the required propulsion power, or monitoring of the hull resistance due to fouling. It's suggested that since sensors are already found on-board, along with equipment to transmit the information, continuous monitoring can be achieved with an adequate analysis. The research presented in this paper, uses a similar approach, with the well-defined goal of plotting accurate speed and fuel consumption curves from relevant operational data, whilst overcoming intermediate factors normally taken into account.

2. Factors affecting ship's fuel consumption.

Typically, a ship's power vs. speed curve is prepared during the delivery sea trials. Power is a more stable parameter compared to fuel consumption and hence easier to be measured. On the other hand, the corresponding ship's speed is measured, being the most significant parameter determining both the power and the fuel consumption.

In addition to increases in speed, resistance and fuel consumption increase by any of the following three parameters:

- Increased draft and displacement
- Worsening of weather conditions
- Worsening of hull and propeller roughness

Theories and methods on the estimation of the contribution of each of these parameters on increased resistance and fuel consumption can be found in the study. However, most are based on experiments obtained from series tests on specific types of ships and hull forms. Therefore, a statistical voyage analysis was carried out for investigating the influence of ship's draft, of the weather and the hull and propeller condition to produce the fuel consumption vs. speed curve, which represents a more realistic and accurate approach for contemporary ships, as required. The approach assumes that predictions based on a previous year's performance are more accurate and reliable than based on sea trials. The existing power-speed curve has two drawbacks. First, when fuel efficiency and CO2 emission are of concern, the fuel consumption is more important to be calculated than the engine power.

Secondly, the production of a single curve during sea trials is far from adequate for the entire ship's lifetime, and such a curve is truly theoretical rather than practical. In addition, the operators do not have an analytical and systematic method to come up with a more accurate, updated curve, which is applicable for aged ships, not only for new ones. By computing a fuel consumption and speed curve, with high degree of preciseness, a more reliable estimation of the fuel needed in a future voyage or even for a sister ship is likely to be obtained. A simple example for appreciating the importance of establishing such a method can be drawn by taking into account that the main expense of ship owner under voyage charter - fuel cost and considering yearly running days.

Hence, a small deviation in the fuel calculation immediately is reflected in an operational cost significantly higher or lower than the predicted, which means that operators can respectively decrease their expected revenue, or loose fixtures. It is therefore essential for decision making, to have better predictions of the fuel consumption, particularly nowadays due to the diminished profit margin of the shipping business and due to the interest in running lower emissions ships. An investigation of the bunker consumption as function of speed is made, which tries to identify the behavior of the relationship.

A lot of the work is based on a preparatory investigation that indicates that the consumption is expressed with a specific S-shape. The project confirms that the consumption reported in the material of the fleet expresses the specific S-shape. The specific reason to why the Shape exists is however not certainly concluded. However, they also suggest that the ship shall have other dimensions and have an increased speed in order to the S-shape to be expressed in the residual resistance. The statistical analysis of the material suggests an S-shape but with some indications that the S-shape might be an illusion within the material because of practical operational conditions or model manipulations. Further work is recommended for full comprehension of the problem and a reproduction of the investigations by others with equipment and material of higher accuracy.

The main objective of this research is to investigate how the bunker consumption changes in relation to the vessel speed. The project needs to identify the real shape the consumption-speed model should follow. Further interest is put on the reason to the behaviour.

A thorough breakdown of the objectives is aligned below.

- Identify the relation between the bunker consumption and vessel speed reported in the SDD.
- Investigate known empirical methods established previously were used to calculate bunker consumption when oil tankers carried out speedup activities, which describes the relationship between the resistance and vessel speed.
- Formulate a new or refined function model that describes the bunker consumption as function of speed more accurate.
- Validate the established model by comparing how the model relates to previous methods of calculation.
- Attempt to refine the complete performance model using the refined consumption speed model.
- Investigate how statistical methods can be used for improving the quality of the performance model..

3. Methods.

Most of the investigations made within this report are based on regression analyses. A regression is a method with purpose to find the optimal coefficients of a function in order to adapt the function to real measured data. Simply expressed, it tries to adapt a function to a set of data as good as possible. It is important to understand that the resulted function of the analysis will always be an estimation of the data. The accuracy of that estimation will vary according to the nature of the analysed data and the specific regression algorithm. Before any regression can be made, it is vital to understand the behaviour of the data and treat it accordingly. Some preparatory work may be necessary before the data can be analysed in order to assure significant results. As have been discussed before, the literature infers that these methods are rough estimations. The methods have moreover been quite difficult to calculate accurately as the methods refer to some significant increases in the resistance due to variations from the "normal" hull shape.

Ultimately, there is a lack of experience among the author of this report for comparing these methods in relation to realty. The extent of the inaccuracy of the methods is unclear and this makes it difficult to conclude anything for certain.

- It should also be mentioned that there is a significant difference between the resistance curves presented and the practical interpretation of the bunker consumption within the SDD. The empirical methods describe the resistance of the ship when dragging the ship, or rather the model, forward. The resulting resistance is measured by the force between the forwarding force and the ships repel.

- The resistance created by the ship and its surroundings are in other words measured directly without any interference of mechanical efficiency or complications. Within the performance modelling of the SDD however, the circumstance is different. The SDD returns the engine's interpretation of the resistance since it reports the bunker consumption.

- The bunker consumption measures how the engine performs, not directly the ship. A further develop of this discussion is delayed to the final discussion.

The results presented in this report strongly suggest that the presence of the S-shape is expressed by the SDD material. As the performance model however manipulates the material this is also a possible reason to the presence of an S-shape. Some further investigations of the models need to be made. At this stage, there exist some suspicions about the deadweight model and some possible unknown effects caused by performance changing factors, such as hull fouling. These two suspicions need to be investigated further. However, it is already possible in some extent to discuss the results found by Eriksson in the validation process 2010. Eriksson calculated the mean value of the consumption and of course, the first question that comes up is if the mean value is an accurate estimation of how the relation should look like. The assumption of the material being normal distributed and the confirmation of this assumption at this stage, can confirm that the mean value is a correct estimation. If the collection of the reports for every individual treated speed can be considered as normal distributed, the mean value is the optimal estimated value of the relation, as the mean value is the origin of the distribution.

The results indicate that it is possible to increase the accuracy of the performance model by implementing more models. Furthermore, as have been shown by the Family class, some implementations of more models cause a different behaviour of the material. The comprehension of the material is of course the most important objective of making these investigations. It is important to understand how the material should be treated and how the specific bunker consumption really behaves. If the S-shape is an illusion, implementations of additional models in the performance model could increase the understanding of the SDD material. In the results above, the reanalyse of the deadweight factor has to some extent been a failure. The reason of this has not yet been concluded. As have been mentioned, sometimes it is very difficult to get adequate results from the regressions. It is recommended to make further attempts of improving the deadweight model. It is important to analyse which different approaches of the problem can be used. How should the objective function look like, what should be minimised and should the regression be made on untreated data or maybe the mean value of the data? What is the best model to simulate the behaviour and should the deadweight model adjust consumption rates to some reference value, as the banana condition? These questions need to be investigated. As surely can be realized by the very breakdown of these questions is that it is actually very difficult and time demanding to analyse just one of these models. There are many possible approaches and it is difficult to predict the outcome before an attempt has been made. Improving the

Performance Model Until now, the focus has been put on the consumption-speed model with some investigations of how this behaviour changes with different hull fouling or loading conditions. We should tend to go further by attempting to improve the complete performance model. The expectation is that the refined consumption speed model will make it possible to improve the other models in the performance model as some of the scatter in the SDD is described with a higher accuracy. Conditions that might explain S-shape If the S-shape could be considered as an illusion, there should exist rational explanations to this behaviour. Even if such occurrences have not been fully discussed until present, there exist thinkable causes that could possibly take the shape of the particular declination of the bunker consumption. There is no or little evidence of such effects presented in this report, but it is still important to discuss. The theory is that these thinkable effects are consequences of the very limitations of propulsion power in the top-speed range. One ship can have different loading scenarios or different operational conditions, such as water salinity and global currents. The fundamental idea here is that the ships resistance can be altered by outer conditions or ships loading condition. It is clear that all of these factors affect the top-speed of the ship. The top-speed of the ship is a balance between the propulsion power and the resistance of the ship. The top-speed is clearly less for a heavily loaded ship than for a non-loaded ship. The actual consumption is always adjusted to the corresponding banana loading condition, but there are never any adjustments to the speed. Of course, it easy to believe that there is no need to any adjustments since the speed is reported in the SDD, or is it necessary? As can be observed in the SDD content table, the reported speed or the calculated speed is the speed over ground based on data supplied by the global positioning system. As a result, the actual experienced speed on the water is not considered. Any global current that speeds up or slows down the ship, or any other resistance interference, affects the top-speed of the ship. Nonetheless, there is still one variable that will be hold constant at all of these conditions, and that is the bunker consumption. The bunker consumption at full power is not influenced by the resistance, but by the very limitations of the engine.

Due to engine dimensions and components, the engine can only consume as much fuel it can swallow and then again exhaust. This is limited by the engines inlets and outlets dimensions, ability to compress air and cooling efficiency. In full power, the consequence is that the same consumption can be measured for different speeds. Furthermore, these effects can be affecting the whole speed range, not only the top-speed. However, it is only at the very top-speed that the effects will become visible as the typical S-shape. Alternatively, that is at least the idea. The reasons to why some of the effects, like global currents, is not accounted for today, is the idea that if the average of the data is calculated for enough time, the difference will cancel each other out. For some of these effects, that is probably true. In order for the difference to cancel each other out, it is crucial that the difference either behaves random or that the error is equally sized on both sides of the added and reduced resistance. With the example of the global currents, the situation might be different. According to discussions with Eriksson, the ship travels back and forth of its given path about four or five times at the time of the running average of eight hundred hours. The power of the global currents is more or less constant at these topical time intervals. That means that if the ship is travelling along a global current two times and against it two times, the sum of the added and reduced consumption of these four trips is about zero. If the ship however has enough time to take an additional single trip along the current, the consumption will become affected with as much as one of these trips affects the consumption, regardless if it is on the plus or minus side. The conclusion of the above thinkable occurrence is that any effects causing the declination of the consumption rate in the higher speed region has little influence on the rest of the speed range. Furthermore, since the practical importance of simulating a more or less rare occurrence, the implementation efforts contra the profit of it, must ultimately be left to be decided. There are however other scenarios when such effects become more important to simulate and that is the calculations of the PF-trend diagrams, for an example.

Whenever a smaller sample of the data is considered, the calculations become much more sensitive for operational conditions that might be disregarded for bigger samples. Therefore, whenever tanker owner makes a PF-trend diagram for monitoring the performance of a ship, these factors is possibly more important to model. If the S-shape is an illusion, the effects creating the illusion are probably not today accounted for and therefore the consumption-speed relation must adapt to this fact. If this is the case, the S-shaped consumption is today the best model for the current performance model. If the performance model would take considerations to global currents and the change in speed, the consumption-speed model might change. The improvements importance The report has showed some results that would increase the accuracy in some narrow speed intervals. The practical implementation of this for judging the performance of the ship would probably not have a strong effect. All of the improvements are made within the confidence level and as the performance are monitored by calculating mean values of periods including speeds reported over the whole range; the real practical implementation of these results would probably not have a visual effect. Only if the ship happens to be running in the same speed within the narrow speed intervals then the improvement could become visual, but such an occasion must be considered as extreme. Observed within the PF-trend diagrams based on the new models, is that the oscillating behaviour still occurs and is not visually improved by the new models. It is therefore recommended to look into other possible models or investigations rather than investigating or implementing a new consumption-speed model in order to improve the PF monitoring.

Conclusions

The S-shape in the consumption-speed relation is in every investigation within this report confirmed to exist within the SDD, and it is with the best confidence that such can be concluded. The very cause to the behaviour and if the consumption should behave as the relationship suggests, cannot be concluded at this time. The strong declination in the highest speed region is probably caused by cooperation between operational conditions and propulsion limitations. Nonetheless, it is strongly recommended that further investigations is followed, as the PF-trend diagrams is much likely affected by these possible misguidance. Ideas of Further Work Many different approaches could have been done in the investigations made within this report. As a suggestion, the investigation of banana and ballast differences and the PF-trend separations could have been investigated in a more statistical matter rather than the trial and error approach made within this report. The real relation between these should have been investigated by looking at diagrams of how the deadweight, for an example, differs with bunker consumption. If the deadweight is in question, the relation to other things must be investigated. The problem with this approach is that the scatter in the SDD makes it occasionally difficult to see any relation and the approach might not be successful. The approach used in this report has at least shown an indication of how the behavior changes when conditions of the ship changes. Furthermore, indications show that the application of more models can increase the accuracy of the performance model as discussed earlier. In further work, it is recommended to investigate the ability and possible improvements of implementing more models in the performance model used today.